PECTIC MATERIAL IN ROOT HAIRS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 286

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It has been observed for some time that many soils show some acidity, that plants are able to take up much more mineral matter than can easily be extracted from soil, and also that although fertilizers are made up of soluble salts, the virgin soils are composed largely of difficultly soluble salts, and after they have been cultivated a few years, yield as full crops if not fuller than those treated with ordinary fertilizers. This has given rise to the question whether there may not be something in the structure of the root hair which enables it to change the difficultly soluble salts to such a form that they can be dissolved and taken into the plant; and since root hairs are so ephemeral, any chemical effect they may have upon the soil will not be present very long in one place.

Since many soils were found to be somewhat acid, and yet most plants cannot grow in an acid medium, two explanations were offered for this phenomenon; first, that there was an acid in the soil which, for lack of a better name, was called humus acid; and secondly, that negatively charged colloidal particles either in the plant tissues or in the soil broke up the salts and released the acids into the soil.

BAUMANN and GULLY (cited by SKENE 6) investigated this matter with peat and mosses, and found that when put into a sodium chloride solution, these plants were able to absorb the positive ion and thus release the chlorine, which, combining with the hydrogen ion, made hydrochloric acid. SKENE (6) made similar tests upon sphagnum, using copper chloride solution, and found that the moss had taken up the copper, releasing the chlorine, which again formed hydrochloric acid. WIELER (8) also tested the higher plants, such as the needles of the pine, the leaves of the horse chestnut, American oak, and yellow lupine, and found that they were all acid, and concluded that the decaying vegetation

would explain the presence of acid in the soil. Again, ODÉN (3) found in the plants that he examined a gelatinous material of the nature of pectic acid, and MANGIN (1) found that pectose is often formed in young cells before cellulose, and that the middle lamella is calcium pectate. He (2) also found that pectose can be changed to pectic acid or pectin by gently heating in 2 per cent hydrochloric acid.

SAMPSON (5), in investigating abscission of the leaf of *Coleus*, found that there was calcium pectate in the middle lamella just before the time of abscission, but that the calcium was lacking at abscission, and discovered that this was due to the pectic acid forming so much more rapidly than the calcium was supplied that the middle lamella was broken down. Miss ROBERTS (4) also examined root hairs of a number of seedlings grown in moist air and found that they all had a layer of pectic material outside the cellulose wall, and often at the tip of the hair there was a layer of callose.

In order to determine whether this condition is general, the root hairs of twenty economic plants grown in sand and in loam were examined, and those of a few seedlings grown in Knop's solution. These seedlings were selected with the idea, first, of getting as great range as possible, and secondly, of comparing several in the same or closely related genera. These root hairs were tested microchemically for cellulose with iodine and 70 per cent sulphuric acid, which turns cellulose bright blue; for callose with resorcin blue, which causes callose to swell and to turn blue; for acidity with neutral red (and later with the Clark and Lubs indicators to determine the degree of acidity); for calcium pectate with ammonium oxalate, which unites with the calcium pectate when calcium oxalate crystals and ammonium pectate are formed; and for pectic material in general with ruthenian red. Of the special forms of pectic material chiefly found in plants, pectose is found especially in young tissues, is insoluble in water, but can be changed to pectic acid or pectin by gently heating for twenty minutes in a 2 per cent solution of hydrochloric acid. Pectin is soluble in water, and pectic acid is soluble in a 2 per cent solution of potassium hydroxide when gently heated for twenty minutes.

TABLE I

Seeds	Ammonium oxalate and calcium pectate form calcium oxalate crystals and ammonium pectate. Test for calcium oxalate crystals		Ruthenian red for pectic material, in general; 2 per cent potassium hydroxide for pectic acid, which is dissolved by it; 2 per cent hydrochloric acid for change of pectose: pectin soluble in water. Test for pectic material	
	Loam	Sand	Loam	Sand
Beans (Kentucky wonder)........	Many crystals	Many crystals	Thick layer; pectose changed mostly to pectic acid	Pectose changed to pectin chiefly, some to pectic acid
Beans (Bush lima)..	Few crystals	Few crystals	Pectose changed chiefly to pectin, some to pectic acid; thin layer	Thin layer; changed chiefly to pectic acid
Beans (Pole lima)..	Many crystals, especially in older root hairs	Many crystals	Thick; pectose changed to pectic acid	Thick; pectose changed to pectic acid
Beans (Golden wax)..........	Very few crystals	Very few crystals	Thick layer; pectose changed to pectic acid	Same as in loam
Cabbage (Chinese).	Crystals fairly abundant	Many crystals	Pectose changed largely to pectin	Same as in loam
Cabbage (Early Jersey Wakefield).........	Very few	Many crystals	Thick layer; pectose changed to pectic acid	Same as in loam
Carrot (Danver's half long)......	?	?	Thick layer; pectose changed to pectic acid	Same as in loam
Corn (Yellow bantam).......	Many crystals	Many crystals	Thick layer; pectose changed to pectic acid	Same as in loam
Cress (Doubled curled)........	Very few	Very few, even less than in loam	Pectose changed to pectic acid	Pectose changed to pectin chiefly, some to pectic acid
Cucumber (Early fortune).......	Almost no crystals	Almost no crystals	Thin layer; pectose changed mostly to pectin, some to pectic acid	Thin layer; pectose changed mostly to pectin

TABLE I—*Continued*

Seeds	Ammonium oxalate and calcium pectate form calcium oxalate crystals and ammonium pectate — Test for calcium oxalate crystals		Ruthenian red for pectic material, in general; 2 per cent potassium hydroxide for pectic acid, which is dissolved by it; 2 per cent hydrochloric acid for change of pectose; pectin soluble in water — Test for pectic material	
	Loam	Sand	Loam	Sand
Egg plant (Black beauty).......	Many crystals	Many crystals	Thick layer; pectose changed to pectic acid	Same as in loam
Lettuce (Mignonette)..........	Few crystals	Many crystals, especially near tip	Pectose changed chiefly to pectic acid	Same as in loam
Parsnip (Hollow crown)........	Very few crystals	Very few crystals	Pectose changed chiefly to pectic acid	Same as in loam
Peas (Telephone)..	Many crystals	Many crystals	Pectose changed to pectic acid	Same as in loam
Radish (Sparkler)..	Many crystals	Many crystals	Pectose changed to pectic acid	Same as in loam
Squash (Golden Hubbard).....	Many crystals	Many crystals	Pectose changed chiefly to pectic acid, some to pectin	Same as in loam
Squash (Giant summer crook neck).........	Number of crystals	Number of crystals	Pectose changed to pectic acid	Little pectic acid: pectose changed to pectic acid
Swiss Chard (Lucullus).....	Few crystals	Few crystals	Pectose changed to pectic acid	Some pectic acid; pectose changed to pectic acid
Tomatoes (Ponderosa).....	Few crystals	Few crystals	Pectose changed to pectin	Thin layer; pectose changed to pectic acid
Watermelon (Cole's early)..	Many crystals	Many crystals	Some pectic acid; pectose changed to pectic acid	Same as in loam

In general, the root system was found more extensive on those seedlings grown in sand, and the root hairs were much longer.

It was also more difficult to find the young root hairs on the roots grown in sand. Pectic material was found in the outer layer of all the root hairs; some of it was in the form of calcium pectate in practically all the root hairs, much was in the form of pectose, and it was difficult to determine with certainty whether some was in the form of pectic acid. By the application of 2 per cent hydrochloric acid the pectose was changed to pectic acid except in a few instances when some was changed to pectin, and the calcium pectate was broken down to calcium chloride, allowing pectic acid to be set free. Why pectose is changed sometimes to one form and sometimes to the other is still an unsolved problem.

Callose forming an inner lamella of the wall was found in all the root hairs, being somewhat thicker at the tip, especially of the younger root hairs. The hairs grown in the two media did not differ essentially in these respects, except that the callose was somewhat thicker at the tips in loam than in sand. No cellulose was found in the root hair walls. As the root epidermal cell bulges to form a hair, the cellulose inner lamella apparently stretches to its capacity, then breaks, and no more cellulose is formed. It may be that under other conditions more cellulose would be formed.

The root hairs gave an acid reaction in all cases both in the loam and in the sand, but usually somewhat higher in the loam than in the sand. According to the P_H value, they ranged between 6.8–6.0 in the sand and in the loam, and in some cases in loam between 6.0–5.2.

The seedlings of only four species were grown in Knop's solution, and the hairs were quite numerous and symmetrical. Before the seeds were placed for germination in the Knop's solution, it was tested and found to have an acidity of 6.8–6.0. After the seedlings had grown, both the root hairs and the solution were tested for acidity. The root hairs showed about the same degree of acidity or a little less than that of the root hairs grown in the soil, while the solution was also less acid than the original, even becoming alkaline in three of the cases. These root hairs had the same structure as those grown in loam and sand, except that the callose was thicker at the tips and in two of the cases the pectose was changed to pectin.

TABLE II*

Seeds	Resorcin blue changed callose to blue: Callose, Loam	Resorcin blue changed callose to blue: Callose, Sand	Acidity, PH value, by use of Clark and Lubs' indicators: Acidity, Loam	Acidity, PH value, by use of Clark and Lubs' indicators: Acidity, Sand
Beans (Kentucky wonder)	Thick layer, especially on young hairs	Thick layer, especially on young hairs	6.0–5.2	6.0–5.2
Beans (Bush lima)	Thick layer	Thick layer	6.0–5.2	6.0–5.2
Beans (Pole lima)	Thick layer	Thick layer	6.0–5.2	6.0–5.2
Beans (Golden wax)	Fairly thick layer, especially on young hairs and at tip	Thick layer	6.0–5.2	6.8–6.0
Cabbage (Chinese)	Thin layer	Thin layer	6.8–6.0	6.8–6.0
Cabbage (Early Jersey Wakefield)	Thin layer; found on young root especially	Same as in loam	Nearer 6.0	Nearer 6.8
Carrots (Danvers)	At tip only, in young hairs, then all around	Thick in older hairs	6.0–5.2	6.0–5.2
Corn (Yellow bantam)	Thick layer, especially at tip	Same as in loam	4.6–4.4	6.0–5.2
Cress (Doubled curled)	Thick layer	Thin layer	6.0–5.2	7.6–6.8
Cucumber (Early fortune)	Thick layer	Thick layer	6.0–5.2	6.8–6.0
Egg plant (Black beauty)	Thick layer, especially at tip	Thick layer	6.0–5.2	6.0–5.2
Lettuce (Mignonette)	On younger hairs especially	Same as in loam	6.0–5.2	6.0–5.2
Parsnip (Hollow crown)	Thick layer, especially at tip	Same as in loam	6.8–6.0	7.6–6.8
Peas (Telephone)	Thick layer	Thick layer	?	6.0–5.2
Radish (Sparkler)	Some, but root hairs rather old	Layer at tip	6.8–6.0	7.6–6.8
Squash (Golden Hubbard)	Thick layer, thicker at tip	Thin layer, thicker at tip	6.0–5.2	6.8–6.0
Squash (Giant summer crookneck)	Thin layer	Fairly thick layer	6.0–5.2	6.8–6.0
Swiss Chard (Lucullus)	Thin layer, thicker at tip	Same as in loam	6.0–5.2	6.8–6.0
Tomatoes (Ponderosa)	Thick layer, especially on young hairs	Same as in loam	6.0–5.2	6.0–5.2
Watermelon (Cole's early)	Thick layer, especially on young hairs	Same as in loam	6.0–5.2	6.8–6.0

* Cellulose was not found in any of the root hairs.

From these experiments it would seem that some of the acidity of the soil is due to pectic material in the root hairs, and that this

may help change some of the difficultly soluble salts, such as tricalcium phosphate, to a soluble form that can be used by the plant.

TABLE III*

SEEDLINGS GROWN IN KNOP'S SOLUTION

Seeds	Ammonium oxalate and calcium pectate form calcium oxalate crystals and ammonium pectate	Ruthenian red for pectic material, in general; 2 per cent hydrochloric acid for change of pectose; 2 per cent potassium hydroxide for pectic acid	Resorcin blue for callose
	Test for calcium oxalate crystals	Test for pectic material	Test for callose
Cabbage (Early Jersey Wakefield)..........	Many crystals	Thick layer all around; pectose changed mostly to pectin, some to pectic acid	Thick layer; thicker at tip
Cucumber (Early fortune)...............	Few crystals	Thick layer; pectose changed to pectic acid at tip, to pectin at sides	Very thick layer all round
Radish (Sparkler)......	Many crystals	Pectose changed to pectic acid at tip, to pectin at sides	Thick layer, especially at tip
Muskmelon (Rockyford)	Few crystals	Pectose changed largely to pectin	Fairly thick layer

* Cellulose was not found in any of the root hairs.

TABLE IV

SEEDLINGS GROWN IN KNOP'S SOLUTION

Seeds	Acidity, PH value by use of Clark and Lubs' indicators	
	Root hairs	Solution
Cabbage..................	6.8–6.0	7.6–7.2
Cucumber.................	7.2–6.8	8.4–7.6
Radish....................	6.8–6.0	8.4–7.6
Muskmelon................	6.8–6.0	6.8–6.0

Summary

1. No cellulose was found in the root hairs of the species studied.

2. The root hairs grown in both loam and sand have a layer of pectic material on the outside, and within a layer of callose, thicker in some plants than in others, and usually a little thicker at the tips.

3. The pectic material in most of the cases at first is in the form of calcium pectate or pectose; pectic acid could not be detected with certainty. The pectic layer is somewhat thicker in loam than in sand.[1]

4. The root hairs are somewhat acid in the forms studied, and there is a tendency to be slightly more acid in loam than in sand.

5. Whether the acidity of the root hair can be ascribed to the presence of pectic material or to some other cause has not been yet determined with certainty.

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[1] The pectose is usually changed to pectic acid by the hydrochloric acid.